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EXPERIMENTAL REMOVAL OF 17-YEAR CICADA NYMPHS AND GROWTH OF HOST APPLE TREES

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Abstract.—Seventeen-year cicada nymphs feed on xylem sap of most species of deciduous trees. They attain very great densities in apple orchards and are known to damage apple trees during oviposition. Newly hatched nymphs were removed from certain apple trees in 1979 and the growth of these trees was compared to trees where the nymphs had not been removed. During 1980, trees without cicada nymphs experienced significantly increased annual wood accumulation compared to control trees with cicadas. There was no difference in growth between the 2 treatments in 1979 (the emergence year). Despite the small sample size, these results suggest that cicada nymphs reduce apple tree wood increment in the years following the emergence.

Most deciduous woody tree species in the eastern U.S. serve as hosts for cicada (*Magicicada* spp.) nymphs (Butler 1886; Dybas and Lloyd 1974; Lloyd and White 1976; White 1980). Commercial apple, peach, pear, plum and cherry trees are often heavily infested (Marlatt 1907; Asquith 1954; Graham and Cochran 1954; Banta 1960; Hamilton and Cleveland 1964). Adult periodical cicadas, which emerge only every 17 years at any locality in the northern part of their range, are known to be extremely abundant (Marlatt 1907; Dybas and Davis 1962). The adults live for two to four weeks and females oviposit in pencil sized twigs (3–11 mm diam). The damaging effects of egg laying are well established (Riley 1885; Hopkins 1897; Cory and Knight 1937; Smock and Neubert 1950; Graham and Cochran 1954; Hunter and Lund 1960; Lloyd and Dybas 1966; Smith and Linderman 1974; White 1980).

Periodical cicadas spend their 17 or 13 year nymphal development underground. As nymphs, they feed by sucking relatively great quantities of xylem fluid, an extremely dilute source of nutrients (Cheung and Marshall 1973; White and Strehl 1978). Few studies have considered the effects of root sucking nymphs. Assessing the impact of feeding nymphs is very difficult; trees supporting cicadas are not killed and are still capable of growth

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and reproduction. Banta (1960), Hamilton (1961) and Hamilton and Cleveland (1964) observed that apple trees with cicada nymphs were experiencing a cessation of growth and a reduction of yield. They were unable to reduce chemically the cicada population, in a replicated manner, required to test their hypothesis that cicadas were responsible for the "apple orchard decline." Karban (1980) compared the growth of parasitized and unparasitized scrub oak trees (*Quercus ilicifolia* Wang.). Parasitized and unparasitized trees did not differ in the amounts that they grew during the years preceding the cicada emergence, indicating that microenvironmental differences between parasitized and unparasitized trees were not causing differences in growth. In the emergence year and the years following the emergence, trees without cicadas grew significantly more (ca. 30% more radial wood accumulation) than those which supported nymphs.

The purpose of this investigation is to remove cicada nymphs from certain trees but not others (controls) in order to test the effect of root xylem fluid feeding on wood increment of apple tree hosts.

Methods and Site Description

A heavy emergence of *M. septendecim* (L.) and *M. cassini* (Fisher) occurred in the Jenkins-Leuken orchard near New Paltz, Ulster Co., N.Y. during the 1st week in June 1979 (Brood II). I selected eleven 'Nothern Spy' apple trees (*Malus pumila* Mill.) (Fig. 1). By late June all of these trees contained many freshly constructed eggnests. Apple trees of other varieties

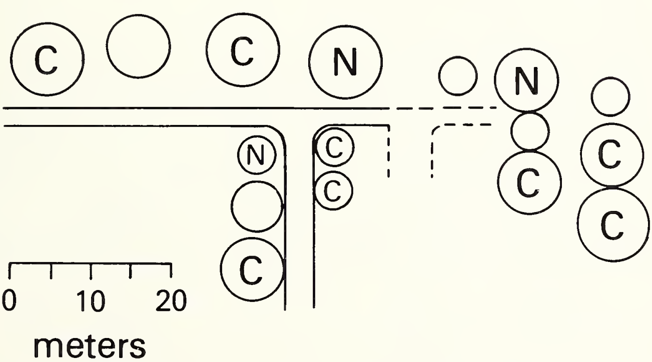

Fig. 1. Scale diagram of the study area. Circles with letters are 'Northern Spy' apple trees that are included in the study. Circles without numbers are either a variety other than Spy or were dead, hollow, or rotting Spy trees. The size of the circle represents the approximate extent of the canopy of each tree. There is no apparent relationship between canopy diam and tree growth. Trees in which cicadas were removed in 1979 are marked "N"; trees with cicadas are marked "C." The location of an overgrown farm road is indicated.

Fig. 2. Bed sheets are set up under one of the experimental trees. As nymphs hatch they fall from the twigs to the ground to begin their subterranean development. Sheets are used to remove the nymphs from the experimental trees.

and trees which were dead, had fallen or had rotting or hollowed trunks were not included. None of the eleven trees in this experiment had been cropped in 1979 or 1980; previous cropping history is unknown.

Three of the eleven trees were selected at random and served as experimental trees. Cotton bed sheets, used to entrap the newly hatched nymphs, were spread under the canopies of the experimental trees on July 2, 1979. The sheets were raised off the ground by wooden stakes at their corners and rocks were placed in them to keep them from flapping in the wind and discharging their contents (Fig. 2). The sheets allowed rain water to pass through but caught the nymphs and unwanted debris. Nymphs were removed from the debris which was then placed on the soil under the sheets. Eight trees had no sheets placed under their canopies and serve as controls.

Once a female places her eggs in a twig they require 6 to 10 weeks to hatch. The 1st instars hatch from their twig-borne eggs, fall to the ground and burrow into the soil. Nymphs from the experimental trees were intercepted in the sheets as they attempted to fall to the ground, leaving the experimental trees free of cicada nymphs.

The density of 1st instars was estimated for the experimental trees by placing five aluminum trays (29 × 23 × 11 cm) on the ground under the canopy in a manner so that they were not covered by bed sheets. Each tray was filled with a saturated picric acid solution and intercepted an area equal to one-fifteenth of a square meter (White 1973; Karban in press). The trays were not allowed to dry out, overflow, or be covered by spider webs. The trays were set out on July 16 and were removed on Aug. 30 after all the nymphs had hatched out and fallen.

The 3 experimental and 8 control trees were cored on Dec. 6, 1980 with an increment borer. The cores were stained with a solution of 1% phloroglucinol in 95% ethanol. To prevent bias, an assistant who did not know which of the cores were from the experimental trees, measured the annual wood increment with a dissecting microscope and an ocular micrometer. Annual wood increment was measured for a 10-year period from 1971 to 1980. Although it was possible to measure more years, the probability of counting a false ring increases as more years are included. One of the control cores was particularly difficult to measure and is not considered in the analysis.

Results

The radial growth increment for the 1980 growing season for each tree is presented in Table 1. There is a 7-fold difference (0.5 to 3.5 mm) in radial growth for 1980 among the trees, irrespective of treatment. From year to year, some trees grow consistently more than others; this is undoubtedly due to habitat, cropping, competitive and predator differences. Comparing

Table 1. 1980 and 1979 annual radial increments (mm) for control trees with feeding cicada nymphs (with cicadas) and experimental trees without cicadas (no cicadas). The 1979 season, which was the emergence year, and the 1980 season are compared to the 8-year (1971–1978) average for each site.

Treatment	8-year average increment (1971–1978)	1980 increment	1980 increment / 8-year average	1979 increment	1979 increment / 8-year average
No cicadas	1.45	1.4	.97	1.8	1.24
No cicadas	1.91	1.8	.94	0.6	.31
No cicadas	2.88	3.5	1.22	2.0	.69
With cicadas	1.50	1.0	.67	1.2	.80
With cicadas	2.09	2.0	.96	2.3	1.10
With cicadas	2.33	1.8	.77	3.1	1.33
With cicadas	1.38	0.7	.51	0.6	.43
With cicadas	2.96	0.9	.30	2.1	.71
With cicadas	2.46	2.8	1.14	3.3	1.34
With cicadas	1.23	0.5	.41	0.7	.57

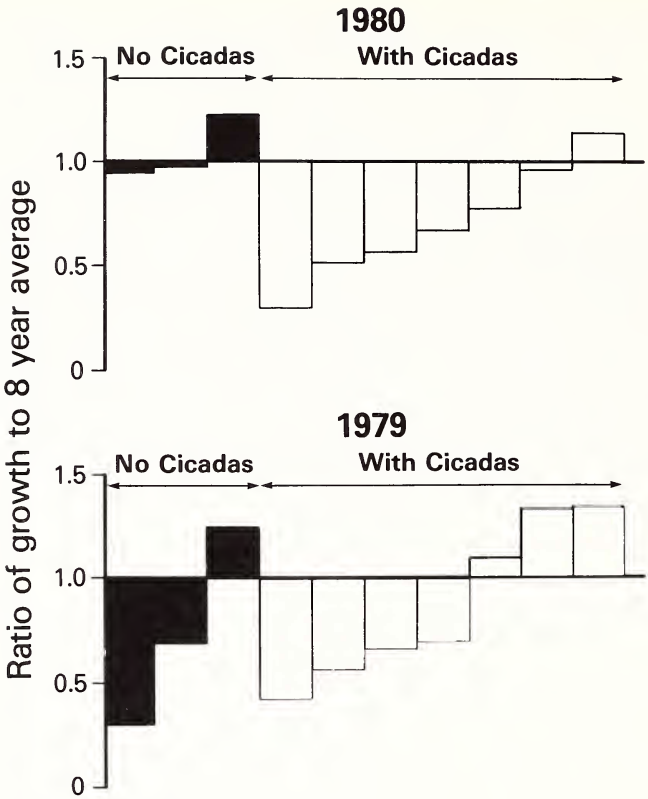

Fig. 3. The ratio of annual wood increment for 1980 and 1979 compared to the 8-year average (1971–1978) for each tree. Trees without cicadas are shown as shaded bars, trees with cicadas are shown as unshaded bars. In 1980, trees without cicadas were ranked 1, 3, and 5. In 1979 trees without cicadas were ranked 3, 7, and 10.

the 1980 annual wood increment with an 8-year average (1971–1978) increment for each tree provides a more meaningful estimate of the effects of the removal of cicadas on tree growth than considering 1980 growth alone. By comparing the 1980 growth to the 8-year average for each tree, the effects of other factors, which each year create differences in growth between the trees, are controlled. There is less than a 3-fold difference in average wood increment over an 8-year period between the trees (1.23 to 2.96 mm). Table 1 and Fig. 3 present the ratio of 1980 increment to the 8-year average for each tree. The ranks of this ratio are compared using a Mann-Whitney U test. The null hypothesis is that there is no effect on radial wood increment of removing the nymphs, i.e. that the samples from the experimental and control treatments come from populations having the same distribution. This null hypothesis can be rejected with 94% certainty ($U = 3$, $n_1 = 3$, $n_2 = 7$, $P = .058$).

This same analysis was applied to the annual radial wood increment for the 1979 growing season (the emergence year). Table 1 and Fig. 3 present the ratio of the 1979 increment to the 8-year average for each tree. The hypothesis that trees without cicadas added relatively more wood than those with nymphs during 1979 is not supported by the data ($U = 7$, $n_1 = 3$, $n_2 = 7$, $P = .258$).

There is no relationship between canopy diameter and tree growth. Mean canopy diameter of the three experimental trees was 7.467 ± 1.746 m and mean canopy diameter of the eight control trees was 6.625 ± 2.271 m (Mann-Whitney $U = 5$, $n_1 = 3$, $n_2 = 7$, $P = .133$). Canopy diameter was not correlated with average radial growth over the 8-year period of 1971 to 1978 (Kendall rank correlation $N = 2$, $n = 10$, no significance). Canopy diameter was not correlated with the ratio of radial growth in 1980 to the 8-year average (Kendall rank correlation, $N = 30$, $n = 10$, no significance).

The density of first instars was estimated by catching a sample of those falling from the tree. The estimated density and SE for each of the three experimental trees is: 777 ± 56, 1,404 ± 144 and 1,914 ± 252 first instars per m^2. This range of densities corresponds to 20–40 adult cicadas per m^2 (Karban in press) and is comparable to nymphal densities found in other studies in apple orchards (Hamilton 1961; Forsythe 1976; Maier 1980).

Discussion

In a previous study the effects of cicada nymphs on annual wood increment were most apparent in the years immediately following the emergence year (Karban 1980). In this study experimental removal of cicadas resulted in increased radial growth of apple trees in the year following the emergence. The reduction in wood increment associated with cicadas has now been shown for apple trees as well as scrub oaks.

Experimental trees, without cicadas, added on average, 61% more radial wood in 1980 than did control trees, with cicadas. This result was not due to other differences between experimental and control trees. However, the experimental trees added 12% more wood over the 8-year period (1971–1978) than did the control trees. Scrub oaks, without cicadas added 30% more wood, on average, than trees with cicadas (Karban 1980).

No signficant differences in annual wood accumulation during the emergence year, 1979, were found between apple trees without cicadas and trees with cicadas. This is in contrast to a previous study in which scrub oaks with no eggnests in their canopies added significantly more wood during the emergence year than did those with eggnests (Karban 1980). This suggests that the negative effect on tree growth observed for the scrub oaks during the emergence year probably resulted from oviposition damage.

Periodical cicada nymphs feed on root xylem fluid (White and Strehl 1978). Amination, the process of incorporation of inorganic nitrogen into organic compounds, takes place largely in growing root cells; most of the nitrogen ascending the stem is already in the form of amino acids (Bollard 1957; Raven et al. 1976; Tromp and Ovaa 1976; Dickson 1979). Wiegert (1964) points out that xylem feeding insects may be extremely costly to their host plant because they consume the nitrogen which the plant requires for growth.

This study has shown that 1st instar cicadas can negatively affect the radial wood increment of apple trees. However, the small sample size, both in terms of the number of trees in the study and in terms of the number of years in which the effect has been found, suggest caution about generalizing from this result.

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